VII.—*On the Formation of Fjords, Cañons, Benches, Prairies, and Intermittent Rivers.* By ROBERT BROWN, F.R.G.S, &c.

Read, March 8, 1869.

I HAVE classed the several physical features enumerated in the title of this communication together, not only because they are all found in the same geographical region, but because many of the causes producing them are mutual, and necessary to a right understanding of all four.

1. FJORDS.—Intersecting the sea-coasts of various portions of the world, more particularly in northern latitudes, are deep, narrow inlets of the sea, surrounded generally by high precipitous cliffs, and varying in length from 2 or 3 miles to 100 or more, variously known as "inlets," "canals," "fjords," and even, on the western shores of Scotland, as "lochs." The nature of these inlets is everywhere identical, even though existing in widely-distant parts of the world, so much so as to suggest a common origin. On the extreme north-west coast of America they intersect the sea-line of British Columbia to a depth, in some cases, of upwards of a hundred miles, the soundings in them showing a great depth of water, high precipitous walls on either side, and generally with a valley towards the head. On the eastern shore of the opposite Island of Vancouver no such inlets are found, but on the western coast of the same island they are again found in perfection; shewing that, in all probability, Vancouver Island was isolated from the mainland by some throe of Nature prior to the formation of the present "canals" on the British Columbia shore, but that the present inlets on the western shore of Vancouver Island formed, at a former period, the sea-board termination of the mainland, and were dug out under conditions identical with those which subsequently formed the fjords now intersecting the coast.

Jervis Inlet may be taken as the type of nearly all of these inlets here, as well as in other portions of the world. It extends in a northerly direction for more than 40 miles, while its width rarely exceeds 1½ mile, and in some places is even less. It is hemmed in on all sides by mountains of the most rugged and stupendous character, rising from its almost perpendicular shores to a height of from 5000 to 6000 feet. The hardy pine, where no other tree can find soil to sustain life, holds but a feeble and uncertain tenure here; and it is not uncommon to see whole mountain sides denuded by the blasts of winter or the still more certain destruction of the avalanche which accompanies the thaw of summer. Strikingly grand and magnificent, there is a solemnity in the silence and utter desolation which prevails here during the months of winter, not a native, not a

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living thing to disturb the solitude; and though in the summer a few miserable Indians may occasionally be met with, and the reverberating echoes of a hundred cataracts disturb the silence, yet the desolation remains, and seems inseparable from a scene Nature never intended as the abode of man. The depths below almost rival the heights of the mountain summit: bottom is rarely reached under 200 fathoms, even close to the shore.* The deep inlets on the Norwegian coast, known as *fjords*—a familiar name, now applied generally to such breaks in the coast-line—are too well known to require description. On the coast of Greenland are again found similar Sounds, indenting both sides of that island (?), but more particularly the western, or Davis Strait shore. Most of these inlets are thickly studded with floating icebergs, and others are so densely choked with them as to receive the name of ice-fjords. All of these fjords form the highways by which the icebergs float out from the glaciers at their heads, whenever these prolongations of the great *mer de glace* of Greenland (the "inland iis") reach the sea. After a long and careful study of these fjords in most parts of the world where they are found, I have come to the conclusion that we must look upon glaciers as the material which hollowed them in such an uniform manner. Everywhere you see marks on the sides of the British Columbian fjord of ice action; and there seems no reason to doubt but that they were at one time the beds of ancient glaciers, which, grinding their outward course to the sea, scooped out these inlets of this great and uniform depth. At the time when these inlets formed the beds of glaciers, the coast was higher than now. We know that the coast of Greenland is now falling;† and, supposing that the present rate of depression goes on, many glacier valleys will in course of time become ice-fjords. After having seen not a little of the abrading action of ice during three different visits to the Arctic regions, extending in circuit from the Spitzbergen Sea to the upper reaches of Baffin's Bay and westward and southward to the "Meta Incognita" of Frobisher, I cannot side with those geologists who, judging ice action merely from what is seen of the comparatively puny glaciers of the Alps and other European ranges, are inclined to under-estimate the abrading power of the glacier. I do not, however, for a moment pretend to assert that the valleys in which glaciers in the Arctic regions (or elsewhere) now lie were originally formed by the glacier.

* 'Vancouver Island Pilot,' p. 139 (Richards).

† In a paper 'On the Elevation and Depression of the Greenland Coast,' read to the British Association at Exeter (1869), I have given what I consider to be the true explanation of the seemingly contradictory statements on this subject among writers on the Arctic regions.

On the contrary, I am at one with those who believe that these rents were chiefly due to the volcanic disturbances which threw up the mountain ranges, and that the glacier merely took advantage of the depression. However, by long abrasion it hollowed out the valley into the form we now see it in the fjords under description. At this present day, not far from the head of most of these inlets, glaciers are found in the Coast Range and Cascade mountains in British Columbia; and along both ranges marks of old glacier action can be seen 2000 to 3000 feet below their summits, and even near the sea-margin. Such a depression of the coast, with the presence of the lower temperature then prevailing, would fill these fjords with glaciers. I may add, that though Professor Whitney,* on the most hearsay evidence, seems inclined to think that the Northern Drift is not found over Vancouver Island and British Columbia, it certainly exists in a well-developed condition.

2. Cañons. — This convenient word, of Hispano-American origin, is used extensively all over the Pacific to express the high perpendicular clefts through which many of the rivers of the West flow often for miles. These cañons are generally found where the river breaks through some mountain-range, or other obstruction of a like nature, on its way to the ocean. Such are the cañons of the Stiken in Alaska; the cañon of the Fraser in British Columbia; the gorges of the Columbia, Wisconsin and Canadian, or the Cañon of the Colorado in New Mexico. An examination of these cañons shews them to have been caused by the force of the rivers which flow through them, when these rivers contained (as there is every evidence to prove they did at one time) a greater body of water than at present. During the time when these glaciers covered the sides of the Cascade and other ranges adjoining these rivers, a greatly-increased amount of precipitation would swell the volume of these streams, enabling them to score deeply the surface of the plateau, and "force mountain barriers to reach the ocean, cutting deep channels in its shores where we now find them." These rivers seem at one time to have been merely the outlets of great lakes, which emptied themselves into the ocean by one or more small rivulets, creeping through the opposing barrier of mountains by rocky gorges or volcanic clefts. Gradually they seem to have enlarged these clefts until a greater body flowed through them. Some of the lesser emptiers were cut off, and joined their volume to the main stream, giving it importance and strength, until, in the course of ages, they graved their record in the huge

* 'Proc. California Acad. Sciences,' vol. iii. p. 272.

rocky cañons through which they now flow,—the great descendants of the humble outlets by which they once found their way to the country on the other side of the Cascade Mountains and to the Pacific. It appears that many of the rivers of the West have, at one time or another, changed their course and bed. Some of these changes seem to have occurred in very remote times, prior to the present arrangement of the superficial formations. At all events, the gold miner every now and again comes upon these old river-beds in the course of running his drifting-tunnels or sinking his mining-shafts. They look eagerly for them, as they are generally rich in gold. Other changes seem to have occurred in very recent times, and seem to have been mainly owing either to the causes I have attempted to pourtray, or to some volcanic action, resulting in its throwing the river out of its former course into a new channel. Such is the *Grande Coulle* of the Columbia River, well known to all voyageurs. I have spoken of the great cañon of the Colorado River, of which the first published account is contained in the work of Castenada, giving a description of the expedition of Don Francisco Vasquez de Coronado in search of the "Seven Cities of Cibola," in 1540-1, during which time they discovered this river, and named it the *Rio del Tison*. The walls of this cañon are probably 5000 feet in height, and when we consider that the river traverses a magnificent defile of this description for upwards of 200 miles, the effect of the scenery may be imagined. Many years ago, it is said, a party of trappers built a large boat, and made the attempt to descend the river through the defile of the cañon, and were never heard from afterwards. They probably dashed their boat in pieces, and were lost by being precipitated over sunken rocks or high falls. In 1857, Lieutenant Ives, of the United States army, attempted the exploration of this great gorge with a light-draught steamer, but without success; and in 1865 another attempt was made, but resulted in equally unfruitful results.* Its descent is said to have been recently accomplished by an adventurous traveller, who, in the desperation consequent on his pursuit by Indians, made his escape through that dangerous outlet. An almost equally stupendous cañon is that of the Red River of the South. This cañon shows that these remarkable defiles were not formed by any paroxysmal convulsion of nature, for when a tributary stream enters the main river it passes through a tributary cañon. The action of rivers in forming such gorges

* In August, 1865, I sent a detailed account of this attempt to Sir Roderick I. Murchison; but it met the fate of many such documents, and never reached him.

as these in geological and modern times is an important but much-neglected subject in geology.*

3. BENCHES.—On the banks of many rivers of the western slope of the Rocky Mountains are found curious terrace "benches," not unlike in general appearance to the famous "parallel Roads of Glen Roy," but (without stirring up such debateable ground) altogether different in character. These benches are always found to the *east* of the Cascade Mountains, and are well seen at Lilloet, on Fraser River, in British Columbia. Lord Milton and Dr. Cheadle figure them in their 'North-West Passage by Land,' as seen at this point. These benches are generally flat and of a good soil, though, as everywhere else to the east of the Cascades, very dry. From what I have already said in reference to the formation of Cañons, I need scarcely enter into any long explanation of their origin, as it is at once self-evident, if the explanation I have given of the formation of the clefts just named is correct. In a word—these benches were formed when the Fraser (or other river) was a lake, only emptied by some little streams (or a stream), now and then gathering strength, and as barrier after barrier was broken down, these benches mark the successive stages of the lowering of the lake's margin, until it finally sunk into the channel of the river. I have supposed these breaks to have occurred at intervals, as some portion of the wall of the gorge gave way. This level may have continued for years, it may be centuries, when another break happened, and so on; the height of the "bench" marking the character of the gap made each time. These breaks may have been (indeed no doubt were) assisted by the volcanic disturbances, which at a comparatively late period, seem to have riven all the country in that region, and volcanoes in the mountains through which these rivers flow were doubtless the active agents of these disruptions.

The same "benches" can be seen more or less distinctly wherever the physical contour of the country is the same, or where a river is barred from reaching the sea, under similar conditions to what the Fraser bears to the Cascade range. That these benches were not connected with glacier action is shown (among other proofs) by the rich character of the soil, and the total absence of *morainès*, or other marks of glacier action.

* The late Professor Edward Hitchcock, of Amherst, U. S. America, has published a memoir "On the Erosions of the Earth's Surface, especially by Rivers," in 'The Smithsonian Contributions to Knowledge,' vol. ix.; but this treatise I am unable, in the place where this paper is written, to refer to,—a matter which I the more regret as I am convinced, from a familiar acquaintance with many of the venerable author's other researches, that it must contain many strikingly original observations.

These broadly marked "benches" ought not to be confounded with some terraces found on various rivers, such as the Columbia, &c., to the west of the Cascades. These terraces are probably connected with glacier action when the mouth of that river was hollowed for more than a hundred miles of a great and uniform depth. The channel of the Golden Gate (San Francisco) has a maximum depth of nearly 50 fathoms, being greatest immediately in the line of the axis of the chain, through which it is cut, while the bar without, and the bay within, are silted up to within less than 10 fathoms of the surface. The straits of Carquines, near the mouth of the Sacramento, have a maximum depth of 18 fathoms, and in the line of the range which bounds them an average depth of 14. Dr. Newberry* thinks that these phenomena are due to glacier action of a similar character to that which hollowed out the fjords; and on the whole there seems some reason to accept his theory, with reservations. In passing down the Columbia from the Dalles (Lat. 45° 35′ 55″ N., Long. 120° 55′ W.) to the Cascades, a curious feature is seen, which though scarcely strictly coming under any of the headings of this paper, is yet interesting, as helping to explain some of the phenomena of bench and cañon. Under the water can be seen, standing upright and firmly rooted in the soil, the remains of a forest of *Abies Douglasii* (Lindl.). General Fremont noticed this in his voyage down the river, and attributed it to a landslip. This explanation may be easily proved to be erroneous, and must, I think, though generally received without investigation, give way to a totally different one. The vicinity of the Cascade exhibits marks of recent volcanic action and disturbance of the traps. The Indians even say that, at one time, the river used to flow under an archway, but that during an eruption of Mount Adams this bridge was thrown down, forming an island in the centre, and helping to give rise to the "Cascades." The effect of this would be to form a dam in the water, raising its waters above the scene of disturbance, and submerging the forest which grew down to its margin. The very recent date of this submergence is shown by the sound character of the wood. The "bench" is also well figured in the plate of the Cañon of Psuc-see-qûe Creek (Oregon) in volume vi. p. 85 of the 'Pacific Railroad Surveys.'†

4. PRAIRIES.—The central portion of the American continent, as indeed of Asia and Africa (witness the great "Steppes" and the "Sahara") is almost treeless, and with a correspondingly

* 'Pacific Railroad Surveys,' vol. vi. p. 43.

† On this subject, see also Hector, in the 'Quarterly Journal of the Geological Society,' 1863, p. 399.

small rainfall. The Cascades and the Rocky Mountains prevent the moisture-laden breezes of the Pacific from reaching the tracts under their special influence, and the distance of great prairies from the sea-board of the Atlantic, renders the moist wind of little influence before reaching the country over which the great "plains" extend. East of the Mississippi the rainfall is greater, and here we have an almost unbroken forest. Between the Cascades and the Rocky Mountains, for the same reason, trees are scarce and the climate dry; so much so, that some portions of the country are little better than desert, while immediately to the west of the former range, the slopes of the mountains are covered with luxuriant forest and fertile soil.

Along the line where the treeless and forest districts meet, local causes determine the presence or absence of trees. Belts of timber border the streams, and cover the more porous and absorbent soils, while level surfaces, with fine and unporous soils, sometimes very wet, and sometimes very dry, sustain only a growth of grass, which could endure the alternations fatal to trees. Annual fires have had their influence in extending the area of grassy surface, and over much of their middle ground, by man's intervention, the causes limiting the growth of trees could be removed, and the forest area extended. The forces of nature are here so nicely balanced, that slight causes would make one or the other preponderate. The many theories which attribute prairies to other causes than the want of water are wholly erroneous, and of only local value. On the great prairies west of the Mississippi, every variety of soil and surface fails to sustain trees, and only a change of climatic conditions will there change the grass-covered surface to forest.*

It would, however, be generalising on very imperfect data were we to conclude that all grassy land known vaguely under the term "prairie," was formed under the same conditions; for to the west of the Cascades are also prairies of some extent, due to totally different causes. These West of the Cascade "Prairies" may be shortly enumerated under three heads:—

(1.) "Tide lands" overflowed by the tide only at its highest periods, and of excellent soil. These are almost invariably found at the mouth of rivers, and the absence of trees upon them is due to the overflow by salt water, or the coldness of the mountain flood, which must sap the roots of deeply growing plants like trees.

(2.) Other small prairies are found along the sources of rivers, particularly mountains always marshy from springs, and

* J. S. Newberry, "On the Origin of Prairies," 'Transactions of the American Scientific Association,' 1866 (Buffalo Meeting), and Foster's 'Mississippi Valley.'

producing a growth of plants almost identical with those at 5000 feet on the mountains of North-West America or on the northern regions of Europe and America. The "Cranberry swamps" are of this nature.

(3.) Dry prairies—with rich black vegetable loam—said to be sometimes too rich for wheat. On Whidby's Island and other places on De Fucas Straits, such as Orcas and San Juan Islands, are prairies of this description, which though now high above water, appear to have been formed of a deposit from some river when the distribution of land and water was different from what it is now. The Nisqually plains, the Great Willamette Prairie, &c., are examples. They are generally thinly scattered with oak (*Quercus Garryanus*), and with a very characteristic group of plants, rarely or never found out of such tracts. Often scattered with lakes and clumps of trees, their park-like character has been frequently noticed and admired.* A modification of this, or perhaps rather of the tide lands, is seen in strips of sand, grass lands covered with coarse grass found at various places along the coast, and distinguished by such plants as *Abronia arenaria, A. umbellata, Orobus littoralis, Franseria, Calystegia,* &c. These dry prairies are scattered through the forest land, such as the Squak Prairie, near Seattle, in Washington Territory, and even the Willamette Prairie in Oregon must be classed as of this nature. The Comox Prairie in Vancouver Island, the Cowichan Prairies in the same island, &c., are also of a similar character. What strikes one particularly is the abruptness with which the forest ends, giving these prairies almost the appearance of "clearings" in the forest. They can certainly be produced by no climatic or terrestrial peculiarities, as the neighbouring forest is subject to influences in every respect the same. I quite agree with Dr. Cooper, to whose excellent work on the 'Natural History of Washington Territory' I have been much indebted, that these prairies bear the mark of having been at one time much greater, and that they have been to a great extent produced by burning, either through the Indians, or by the forests catching fire. I know that in various places the forest is now covering tracts which within the memory of man were grassy prairies on which the Indians grazed their horses; and on the Nisqually prairies, only as far back as 1847, several seamen and officers of one of H.B.M.'s vessels, then lying in Puget Sound, were buried on the prairie. Their graves are now in a dense

* Wilkes, 'Exploring Expedition;' Lord, 'Naturalist in British Columbia,' and in 'Temple Bar,' Oct., 1866; Suckley and Cooper, 'Nat. Hist. Washington Territory,' &c.

thicket of trees. Other prairies, such as most of the Willamette Prairies, appear never to have been covered by forest, and great changes seem to have occurred since these were formed. Several species of animals if not confined to the prairies are yet quite characteristic of them, such as the gopher (*Thomomys Douglasii*, Rich.), meadow mice (*Jaculus Hudsonius*, Zimm.), sewellel (*Aplodontia leporina*, Rich.), and the prairie mole (*Hesperomys austerus*, Baird). These animals are principally seen on the Nisqually prairie, and seem, like certain plants found there, to have wandered from the east of the mountains.*

On some of these prairies are peculiar mounds of gravel and soil, which appear to have been produced by some tidal influence when these prairies were covered by the sea. The whole subject of the formation of Western prairies is very interesting, but would lead me into discussion foreign to my subject, so that I can only touch on what would require a volume specially to treat of.†

In connection with this subject, I may mention that in Southern Oregon and other parts, the south side of a hill is generally bare, while the north is covered with vegetation, a fact taken advantage of by the Indian skirmisher.

5. Intermittent Rivers.—All the great rivers of North-West America rise either in the Rocky Mountains or in some of its tributary spurs, and though the Cascade Range gives various tributaries to the rivers which flow into the Pacific, none of them, with the exception of the Willamette, Rogue River, Chehalis, and some smaller streams, have their source in the Cascade Range: indeed the former unites with the larger Columbia, and under that name reaches the ocean. Only one river of the slightest consequence rises on the eastern or arid side of the mountains, viz., the Deschutes, which, after keeping along near the base of the mountains, dashing over falls and between high rocky walls, joins the Columbia just above the "Dalles" of the latter river. Some indeed (like the Klamath) take their rise in lakes, fed by streams from the mountains, and gathering strength find their way to the Pacific through some of the broken portions of the chain immediately south of the 42nd parallel of north latitude. It is only the great rivers such as the Columbia, which gather-

* Cooper, *loc. cit.*

† I have described these Western Prairies, and other points in the physical geography of North-West America, more fully in a memoir entitled "Das Innere der Vancouver Insel" (Peterman's 'Geographische Mittheilungen,' Heftes i.–iii. 1869), in a paper "On the Geographical Distribution of the Coniferæ and Gnetaceæ" ('Trans. Botanical Society, Edinburgh,' vol. x. p. 175); in another, "On the Geographical Distribution and Physical Characteristics of the Coal Fields of North-West America" ('Trans. Edin. Geological Society,' 1868–9), in an official report of my 'Explorations in Vancouver Island' in 1864 (Victoria, V. I., 1865), and in a separate work now publishing, entitled 'Horæ Sylvanæ.'

ing tributaries on every hand, such as the Snake (the Saptin or Lewis River of the older travellers), the Kootane, the Flathead, &c., can muster strength to cross the "great desert" or "basin," and reach the ocean in triumph. The smaller ones are less fortunate and are swallowed up in this Sahara of the west, gradually lessening and lessening until they are lost in the sand. Such are the "sinks" of Carsons and Humboldt rivers to the south. Sometimes these rivers rise and sink several times in the course of a few miles, and their course can only be laid down by alternate dotted and "full" lines. At least we suppose them to be the same river, for in this strange cavernous region another curious phenomenon presents itself, viz., that of small rivers springing cold and clear, like Minerva full armed from the brain of Jove, right from Mother earth, without undergoing any of the preliminary operations which their slow-going sisters suffer in older lands, but again, after describing a sullen course, making fertile some oasis in the desert, disappearing at once under the ground. An even still more curious feature presents itself in some of the creeks flowing from the snows of the Cascades; down their eastern slope sometimes in the forenoon we would encamp by the side of a stream with but barely sufficient water for camp purposes, but on returning in the evening found it roaring and crashing along so full of water as to render the fording of it a matter of difficulty, and again in the morning would find it almost dry, with the marks of last night's flood visible on the wet sand and gravel. I see that General Marcy narrates a similar circumstance when exploring the Red River of the South,* but failed to account for it, though I believe that the explanation I am about to give will be found not very far from the truth. These streams head in high mountains, and the sun is not of sufficient power to melt the snow which forms their volume until late in the day, when they gather force, and again decrease after sunset until they are almost dry. I have seen muleteers near the base of Mount Shasta (14,400 feet) in North California waiting for the rising of the creek, like the children of Israel for the smiting of the rock; and it was sometimes long after dark before the stream would be heard rushing down its former dry bed. So familiar was this phenomenon that sufficient water for breakfast would be saved over night, knowing that the creek would be almost dry before morning.

In this paper, for the sake of conciseness, I have endeavoured to present the conclusions at which I have arrived rather than the data on which these deductions were founded. I trust, however, that I have to some extent presented sufficient facts to

* 'Army Life on the Border' (1866), p. 135.

establish the points at which I have been aiming, viz:—1. FJORDS are in almost every case identical in formation, and were the beds of former glaciers. 2. CAÑONS are formed by the action of river currents. 3. BENCHES are the marks of the successive levels of the river when in the form of a lake, and the successive levels are the results of the sudden breaking down of barriers tending eventually to form the present cañons. 4. PRAIRIES in the interior of America are due to the cause which renders arid the greater portion of the interior of continents, viz., want of rains. 5. INTERMITTENT RIVERS are the result of the dryness of the great basin owing to the moist breezes of the Pacific being intercepted by the peaks of the Cascade Mountains, the melting of the snows, and other minor causes, and the "sinks" of rivers are due to these same causes (especially the drought), and the volcanic cavernous character of the country.

VIII.—*Account of the Swedish North-Polar Expedition of* 1868, *under the Command of* A. E. NORDENSKIÖLD and FR. W. VON OTTER. By A. E. NORDENSKIÖLD and FR. W. VON OTTER.

Read, March 22, 1869.

THE study of the natural history of the polar regions has been of late years prosecuted in Sweden with so much interest that, exclusive of the present year's undertaking, no less than three *

* These were the following:—

The Expedition of 1858, fitted out at the expense of Otto Torell. The following gentlemen took part in the undertaking: O. Torell, A. E. Nordenskiöld, A. Qvenuerstedt. The Expedition visited the western coast of Spitzbergen, and brought home considerable zoological and geological collections.

The Expedition of 1861, fitted out at the public expense. The gentlemen who took part in the expedition, besides the proposer and chief, O. Torell, were A. von Goës, A. T. Malmgren, F. A. Smitt, G. von Yhlen, zoologists and botanists; B. Lilliehöök and W. Kuglenstjerna, commanders of the vessels; C. W. Blomstrand, C. Chydenius, N. Dunér and A. E. Nordenskiöld for geological and physical investigations. The expedition visited, in both vessels, the western and northern coasts of Spitzbergen, made extensive journeys in boats for the purpose of constructing a topographical and geological map of the group of islands, and of examining the northern part of the triangulation for degree-measuring, which the present President of the Royal Society, General E. Sabine, as early as 1826, proposed to get executed, in these high northern regions, and lastly brought home with them a collection of materials for studying the *fauna*, *flora*, and geology of the islands, probably not surpassed in completeness by any similar collections from districts situated at so great a distance from the centres of civilisation.

The Expedition of 1864, fitted out at the public expense, chiefly for the purpose of continuing the survey for the measurement of the degree. The gentlemen who took part in the undertaking were A. E. Nordenskiöld, chief, N. Duner and